APP

RESPONSE OF FOREST FLOOR MICROARTHROPODS TO A FOREST REGENERATION BURN AT WINE SPRING WATERSHED (SOUTHERN APPALACHIANS)

by

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Abstract: We sampled microarthropods in litter and soil of the Wine Spring watershed on April 2, 1995 before the watershed was burned, again on May 9, 1995 immediately following burning, and two years later on June 9, 1997. Pre-burn samples revealed a high abundance of mites (Arachnida: Acari) and collembolans (Insecta: Collembola). Oribatid (Acari: Oribatei) mites were numerous and species-rich. Overall, 112 species of oribatids were identified. The fauna was similar to that described for watersheds at the Coweeta Hydrologic Laboratory, North Carolina, though some additional species not recorded for Coweeta were found at Wine Spring. Groups of microarthropods responded differently to the burning treatment. Prostigmata (Acari), mostly small and delicate forms, were initially reduced to less than 50% of their pre-burn numbers, but recovered after two years. Mesostigmata (Acari) mostly survived the immediate burn but were reduced two years later. Most species of oribatids survived the initial effects of the burn, but numbers were reduced by 55% and species richness by 20%. Over the following two years, the oribatid fauna continued to decline to 28% of pre-burn abundance and 70% of pre-burn species richness. The mosaic nature of the burn left refugia from which microarthropods may re-invade heavily burned areas, once litter layers become restored.

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Introduction

Soil microarthropods, particularly the mites (Arachnida: Acari) and collembolans (Insecta: Collembola) are hyperdiverse taxa with local assemblages composed of hundreds of species (Asquith et al. 1990). Their activity is an important determinant of organic litter decomposition and nutrient mineralization rates (Swift et al. 1979). Estimates of their contribution to mass loss by deciduous leaf litter range from 4% to 43% (Seastedt 1984). They act primarily by breaking up substrates, by stimulating microbial decomposers, and by grazing on microbial growth (Coleman and Crossley 1996, Lussenhop 1992).

The effects of forest management practices on soil microarthropods has been documented in several instances. Clear-cutting generally reduces populations of forest floor arthropods (Huhta et al. 1969, Hill et al. 1975, Seastedt and Crossley 1981), and these reductions may persist for years afterwards (Huhta et al. 1969, Blair and Crossley 1988). Some of these reductions may be attributed to changes in microclimate (Seastedt and Crossley 1981) or other physical factors. Following forest fertilization microarthropods may show population increases (Weetman and Hill 1973, Bailey 1994, Bird 1997), although effects of fertilizers may be largely indirect.

Fire depresses microarthropod populations directly and indirectly through habitat destruction. Recovery of microarthropods from direct mortality impacts will vary with life history, i.e., Collembola and some Prostigmata have greater intrinsic rates of increase than do oribatid mites. Recovery from habitat destruction will depend both on habitat regeneration and recolonization rate of the animals. Most studies of fire effects on soil microarthropods have been done following wildfires, which destroy much of the forest floor. In these instances microarthropod numbers are substantially reduced (Hill et al. 1975, Sgardelis and Margaris 1993, Paquin and Codere 1997). Fewer studies have dealt with prescribed burns. Metz and Farrier (1973) examined forest floors in loblolly pine (*Pinus taeda* L.) stands subjected to periodic or annual burns. They found that numbers of microarthropods were depressed in annual burns but not in periodic ones. Immediately after burning, the number of animals was reduced drastically. Similar results were described for collembolan populations (Metz and Dindal

1975). Species diversity of collembolans in periodically burned plots was increased.

We examined the effects of a prescribed stand-replacement fire (Elliott et al. 1998) on soil microarthropods, comparing immediate (one month) responses and two-year responses to burning. We gave special attention to the oribatid mites (Acari: Oribatei), since that group contains a large number of species in forest soils of the southern Appalachians (Lamoncha and Crossley 1998). The oribatids are a species-rich group generally, and because of their slow life cycles, should be the slowest group to recover from fire damage.

Materials and Methods

The Wine Spring watershed is located in the Nantahala Mountains of the Southern Appalachians. A description of the site, the burning regime and the vegetation responses is given by Elliott et al. 1998 and Vose et al. 1998. Briefly, this study is part of an ecosystem management project initiated with the objective of using and/or developing ecologically based concepts, principles and technology to achieve desired resource conditions. A program of microarthropod sampling was designed to measure pre-burn, immediate post-burn, and two-year post-burn abundance of microarthropods. We sampled soil and litter microarthropods on April 2, 1995 before the watershed was burned, on May 9, 1995 immediately after burning, and finally on June 9, 1997. At each time, samples were taken from six sites on the watershed: two at the base, two mid-slope, and two at the ridge (see Table 1). At each site 15 soil-litter cores were taken at random. The cores were aluminum sleeves 5 cm dia by 5 cm deep. Arthropods were removed from the samples using a modified micro-Tullgren extractor (Crossley and Blair 1991). Samples were sorted using a 20-X binocular stereomicroscope, and separated into mite suborders, collembolans, and other arthropods. Adult oribatid mites were identified to species.

Results

Fire Intensity at Sampling Sites

The intensity of fire varied among the sampling sites (Table 1). We had anticipated a gradient of degree of incineration, but instead the fire produced a mosaic of burned sites. The lowest site (A6) at the bottom of the watershed experienced little burn, judging from the percent of litter incinerated. The most intense burn occurred at site B2, near the ridge. Generally, sites on the lower slopes and on the highest part of the ridge showed the smallest fire damage (Table 1). Our sampling sites represent but a small portion of the areas, and given the mosaic nature of the stand replacement fire (Vose et al. 1998), some variation is to be expected. The June, 1997 microarthropod samples contained significant amounts of charcoal in the litter layers (Table 1), corresponding approximately to the 1995 estimates of burn intensities in our particular sampling sites and thus supporting our earlier estimates.

Microarthropod Abundance

Total microarthropod populations revealed by our sampling were not unusual for the southern Appalachian Region, but declined in the two post-burn periods (Table 2). Pre-burn populations of some 200 microarthropods per sample indicate 100,000 per m^2. Similar estimates (93,000 per m^2) were obtained for a south-facing watershed (WS 2) at the nearby Coweeta Hydrologic Laboratory (Seastedt and Crossley 1981). Lamoncha and Crossley (1998) reported an average of 65,000 microarthropods per m^2 along an elevation gradient at Coweeta. In the immediate post-burn period at Wine Spring (May, 1995) total microarthropod numbers declined to about half of the pre-burn population sizes. Two years later, total populations had declined still further (Table 2).

Before the fire, abundance of the microarthropod groups did not vary significantly as a function of elevation on the slope. Similarly, microarthropod abundance was not found to vary with elevation at the Coweeta Hydrologic Laboratory (Lamoncha and Crossley 1998). In the immediate post-burn period (May 1995) most microarthropod groups were

Table 1. Location of sites for microarthropod samples and estimates of percent burned, Wine Spring Watershed, 1995-1997. Arranged from highest (B1) to lowest (A6) sites.

Site Number	Position on Watershed	Percent Litter Incinerated (visual estimate, May, 1995)	*Charcoal Index (June, 1997)
B1	Ridge	50%	1.3
B2	Ridge	100%	2.1
B3	Mid-slope	75%	2.4
B4	Mid-slope	75%	2.3
A5	Lower Slope	30%	1.5
A6	Lower Slope	None	0.9

*Scale of 0 (no charcoal) to 3 (dominated by charcoal)

depressed (Table 2). Collembolan populations decreased in the mid-slope sites, but increased their numbers above pre-burn population sizes in the lower sites and at the ridge top site, so that average densities post-burn did not differ from pre-burn densities. Collembolans are capable of rapid reproduction (Hopkin 1997) and are able to respond rapidly to disturbances. In South Carolina, frequent or periodic prescribed burns were found to decrease collembolan abundance (Metz and Dindal 1975). Prostigmatic mites exhibited the greatest population declines, to an average of about 25% of pre-burn populations (Table 3). These mites are soft-bodied, delicate fungal feeders or tiny predators, and seemingly highly susceptible to fire on the forest floor. Average densities of the more robust Mesostigmatic mites, mostly predaceous species in these samples, appeared to decline in post-burn samples, but the difference was not statistically significant ($P = 0.10$). Total abundance of oribatid mites declined about 55% (Table 3). Most adult oribatids are heavily sclerotized. Immature oribatids are not, but they did not suffer greater mortality than the adults.

Two years after the fire (June 1997) microarthropod populations again showed a differential response (Tables 2 and 3). Prostigmatic mites had rebounded to pre-burn population sizes. Mesostigmatic mites, oribatid mites and collembolans had reduced numbers generally. Abundance of mesostigmatic mites was less than 30% of pre-burn numbers, oribatids less than 30%, and collembolans about 60%.

Oribatid Mite Diversity

The southern Appalachian forested ecosystems support a large number of oribatid mite species (Hansen 1997; Lamoncha and Crossley 1998). In 90 pre-burn samples from the Wine Spring watershed we identified a total of 112 oribatid species. One month post-burn, we found 90 species; two years later, 78 species. As is usual for soil microarthropods, these communities contain a few common species and many rare ones represented by a few individuals. In pre-burn samples all sampling sites on the watershed contained similar numbers of species (Table 4). Numbers of species were reduced in the immediate post-burn period, from a mean of 65 per site to 48.5 per site. Two years later there was a further reduction in the number of oribatid species to 34.8 per site. Margalef's Index, a measure of species richness, also declined following the burn (Table 4). Endophagous oribatid mites were especially decimated by the burn. These species are obligate burrowers in woody substrates (woody debris, petioles, twigs, needles) as juveniles, and are thus dependent upon the presence of woody microhabitats. They tend towards larger body sizes and, most likely, slower life cycles. They are also functionally distinct from most microarthropods in their direct role in the degradation of substrates (Bal 1970, Hansen 1997). After two years endophages in the ridge and slope sites (sites B1 - B4) had declined to 10% of the pre-burn samples, whereas the lower, essentially unburned site A6 retained 78% of the endophagous oribatids.

Table 2. Abundance of mites and collembolans in samples taken pre-burn, one month post-burn and two years post-burn periods, Wine Spring watershed, 1995-1997. Each number represents a mean of fifteen cores, 5 cm dia X 5 cm deep. Arranged from lowest (A6) to highest (B2) fire intensity.

Site Number	Prostigmata	Mesostigmata	Oribatei	Collembola	Total
		Preburn			
A6	37.7	15.8	103.4	25.1	182.0
A5	65.3	26.9	125.2	28.0	245.4
B1	26.6	11.9	106.1	24.9	169.5
B4	34.8	25.3	112.5	47.0	219.6
B3	46.5	22.6	77.0	38.2	184.3
B2	34.9	13.5	96.7	11.0	156.1
mean	**41.0**	**19.3**	**103.5**	**29.0**	**192.8**
S.E	±5.52	±2.62	±6.60	±5.05	±13.56
		One Month Post-burn			
A6	8.4	15.9	77.0	40.3	141.6
A5	18.7	23.1	79.2	37.6	158.6
B1	13.1	10.4	48.7	32.1	104.3
B4	12.1	12.5	41.7	40.2	106.5
B3	6.9	8.7	54.3	18.1	88.0
B2	3.6	12.5	52.3	8.5	76.9
mean	**10.5**	**13.8**	**58.9**	**29.5**	**112.6**
S.E.	±2.17	±2.10	±6.33	±5.40	±12.83
		Two Years Post-burn			
A6	37.3	7.2	46.3	18.1	108.9
A5	69.0	7.9	43.2	18.2	138.3
B1	16.1	5.2	17.3	11.0	49.6
B4	37.8	6.3	22.3	14.7	81.1
B3	18.5	5.2	16.5	15.6	55.8
B2	58.3	5.2	27.6	12.7	103.8
mean	**39.50**	**6.17**	**28.8**	**15.05**	**89.58**
S.E.	±8.60	±0.48	±5.30	±1.18	±13.85

Table 3. Abundance of mites and collembolans in post-burn samples, as a percentage of pre-burn abundances. Arranged from lowest (A6) to highest (B2) fire intensity

Plot	Prostigmata	Mesostigmata	Oribatei	Collembola	Total
		One Month Post-burn			
A6	22.3 %	100.6 %	74.5 %	160.6 %	77.8 %
A5	28.6 %	85.9 %	63.3 %	134.3 %	63.9 %
B1	49.3 %	87.4 %	45.9 %	128.9 %	61.5 %
B4	34.8 %	49.4 %	37.1 %	85.5 %	48.5 %
B3	14.8 %	38.5 %	56.1 %	47.4 %	47.7 %
B2	10.3 %	92.6 %	54.1 %	77.3 %	49.3 %
mean	**26.7 %**	**75.7 %**	**55.2 %**	**105.7 %**	**58.1 %**
S.E.	±5.78 %	±10.32 %	±5.31 %	±17.23 %	±4.85 %
		Two Years Post-burn			
A6	98.8 %	45.6 %	44.8 %	72.1 %	59.8 %
A5	105.7 %	29.4 %	34.5 %	65.0 %	56.4 %
B1	60.5 %	43.7 %	16.3 %	44.2 %	29.3 %
B4	108.6 %	24.9 %	19.8 %	31.3 %	37.2 %
B3	39.8 %	23.0 %	21.4 %	40.8 %	30.3 %
B2	167.0 %	38.5 %	28.5 %	115.0 %	66.5 %
Mean	**96.7 %**	**34.8 %**	**27.5 %**	**61.4 %**	**46.6 %**
S.E.	±17.92 %	±3.96 %	±4.34 %	±12.37 %	±6.60 %

Table 4. Numbers of oribatid mite species in Wine Spring watershed sites before burning (April 1995), one month post-burn (May 1995) and two years post-burn (June 1997). Arranged from lowest (A1) to highest fire intensity (B2). Variates are species found in 15 samples at each site.

Site Number	Pre-Burn	One Month Post-Burn	Two Years Post-Burn
A6	61	52	41
A5	67	55	42
B1	70	46	31
B4	61	44	30
B3	64	43	30
B2	67	51	35
Mean (SE)	65 • 1.48	48.5 • 1.98	34.8 • 2.24
Total Individuals	9,310	5,202	4,699
*Margalef Richness Index	16.6	12.9	9.8

*S-1/$\log_e$ N. Based on numbers of adults only

The dominant oribatid taxa remained essentially the same ones in pre-burn and post-burn periods. The species complex *Suctobelbella* and the widespread species *Oppiella nova* and *Tectocepheus velatus* were the most numerous of the taxa throughout the sampling period (Table 5). These same taxa are dominant in other southern Appalachian forest floors as well (Lamoncha 1994, Hansen 1997). Their habitat is the lower O layer and mineral soil, rather than the litter layer.

Discussion

Forest fires can have both direct and indirect effects on forest floor invertebrates. Initial heat may destroy populations of some fauna, and long-term effects on faunal habitats and resources may persist for years. Cutting of stands followed by intense fires can reduce the forest floor and decimate the soil fauna, with few survivors (Paquin and Coderre 1997). Critical temperatures for soil mites are around 30 • - 32 • C, at which animals become inactive and subsequently desiccate (Wallwork 1960). Survivors of an intense burn of the forest floor are those species able to escape by migrating downward into the soil. A prescribed stand-replacement fire of the type investigated here will create a mosaic of burned and unburned areas (Vose et al. 1998). We observed that some of our burned sites (Table 1) were surrounded by virtually unburned forest floor. Unburned patches should serve both as refugia from which fauna can recolonize, and as a source of litter input that can begin to restore the litter habitat in adjacent burned areas. In the longer term, opening of forest canopies will increase insolation and decrease soil moisture. Soil microarthropods tend to increase their depth distribution under those conditions (Seastedt and Crossley 1981). With prescribed burning, litter layers may require decades to return to the original depth (Ffolliot and Guertin 1990), litter decomposition rates decline and microbial pools of nutrients may change (Monleon and Cromack 1996). Changes in litter quality may accompany changes in stand composition, if leaf fall consists of significant amounts of herbaceous vegetation or leaves of higher quality (lower lignin content). Our samples of soil microarthropods from the Wine Spring watershed revealed a rich, diverse community of species, resembling other studies in the southern Appalachians. Immediate effects of the prescription fire were seen as reductions in numbers of microarthropods. Given the short time between pre-burn and post-burn samples, we feel confident in attributing differences in microarthropod abundance to effects of the fire.

Table 5. Ranks of the three most abundant oribatid species in sites sampled at the Wine Spring watershed. Arranged from lowest (A6) to highest (B2) fire intensity.

Species	B1	B2	B3	B4	A5	A6
			Pre-burn			
Suctobelbella spp.	1	2	1	2	1	2
Oppiella nova		1	2	1	2	1
Tectocepheus velatus	3	3	3			3
Xylobates robustior					3	
Atropacarus stictulus	2					
Microppia minus				3		
			One month post-burn			
Suctobelbella spp.	1	1	2	1	1	3
Oppiella nova	2	3	1	2	2	1
Tectocepheus velatus	3	2			3	2
Ramusella sp.				3		
Ceratozetes mediocris			3			
			One year post-burn			
Suctobelbella spp.	2	1	1	1	2	1
Scheloribates sp.	1	2	2			
Tectocepheus velatus	3	3			1	2
Oribatula tibialis			3			
Brachychthonius jugatus			2			
Oppiella nova				3	3	
Lasiobelba rigida						3

Unlike canopy arthropods, soil mites do not show rapid changes in population size. In research at the Coweeta Hydrologic Laboratory, Lamoncha and Crossley (1998) found no difference between soil microarthropod abundance in April and May, 1992. Large increases in collembolan populations occur in late winter to early spring in the southern Appalachians (Lamoncha and Crossley 1988; Crossley unpub.). No such increases were seen at Wine Spring, but collembolans either recovered quickly or were not suppressed by the fire (Table 2, 3).

Declines in microarthropod abundance from just post-burn to the census two years later indicates that habitat degradation had long-term effects on rates of mortality and reproduction. Many cores taken after two years contained a substantial amount of charcoal, upon which little or no litter had accumulated. Except for the Prostigmata, which had near complete recovery of overall abundance, all groups were reduced. The majority of the Prostigmata in the samples taken two years post-burn were tiny members of the Family Nanorchestidae. It is likely that the burn is responsible for shifts in abundance of species of Prostigmata. The reductions in other microarthropod groups seemed distributed across all sampling sites on the watershed. The small numbers of endophagous oribatids also suggest a significant change in community structure.

Microarthropod groups will vary in their ability to recover from fires such as this forest regeneration burn. Recovery will depend upon their initial sensitivity to the burn, their intrinsic rates of increase (life history), and their habitat requirements. Fundamentally, re-establishment of the microarthropod community will be determined by recovery of the habitat, although species with slow life cycles and low dispersal rates may lag behind habitat recovery. Initial survival was doubtless aided by the mosaic nature of the forest regeneration burn. Recovery should be aided by the closeness of colonizers, especially important for those species with low dispersal rates, and amelioration of burned patches by improving microclimate and providing leaf litter input.

Acknowledgments

We are especially grateful to Dr. Roy Norton, who provided oribatid mite species identifications. Versions of the manuscript were reviewed by Drs. David C. Coleman and Wayne T. Swank. Research supported by a

cooperative agreement between the USDA Forest Service and the University of Georgia.

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